

*Waste-to-Energy Workshop for the Farm, Food  
Processing, and Wood Industries*

*Gasification & Combustion  
Fundamentals*

*Dr. Robert M. Stwalley III, P.E.*



**Stwalley &  
Stwalley  
Engineering**

**PURDUE**  
UNIVERSITY

Office of Professional Practice  
Agricultural & Biological Engineering

# *Overview*

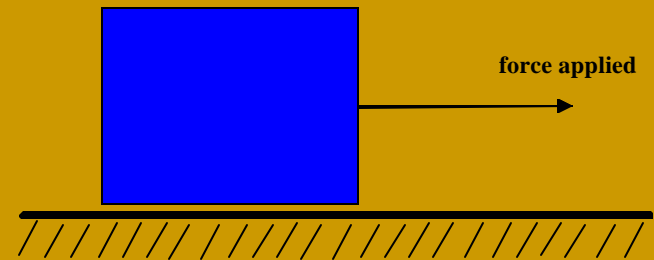
- Energy & Everyday Processes
- Combustion Fundamentals
- Utilization of Combustion
- Gasification Fundamentals
- Utilization of Gasification
- Efficient Use of Energy within Our Lives
- Services & Products Offered

# *Energy & Everyday Processes*

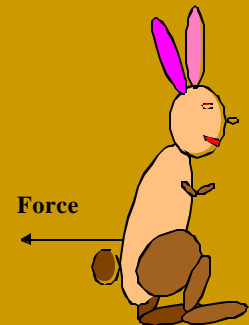
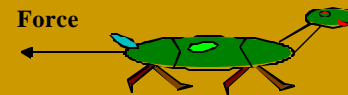
- What is Energy? Power?
- The Thermodynamics Game
- First Law
- Conversion Processes
- Efficiency
- Second Law
- Availability

# *What is Energy? Power?*

- Energy = Work
- Work = Force Applied X Distance Traveled
- Power = Rate of Work  
= Work / Time



$$\text{Power} = \text{Work} / \text{Time}$$



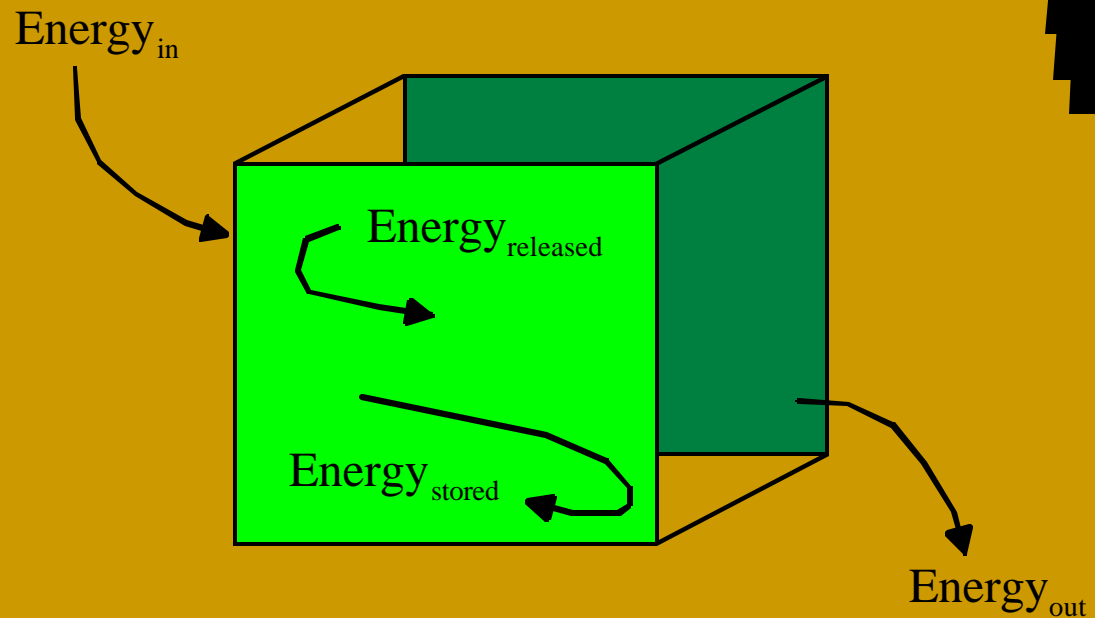
# *The Thermodynamics Game*

- Thermo runs the world!
- We use Energy as it moves about.
- The “Amount” of Energy is a Constant.
- Useful vs. Wasted Energy.
- The “Usefulness” or quality of Energy degrades over time.
- We all must play this game. It helps when you understand it.

# *First Law*

The “Amount” of Energy is  
Always the Same!

# *The Control Volume*



$$\text{Energy}_{\text{in}} + \text{Energy}_{\text{released}} \rightarrow \text{Energy}_{\text{stored}} + \text{Energy}_{\text{out}}$$

# *Conversion Process*

- Gravitational (Potential)
- Chemical
- Nuclear
- Electromagnetic
- Mechanical
- Kinetic
- Rotational
- Thermal



## *Conversion Process (con't.)*

- Society interacts during the process, when the existing “form” of the Energy is transformed into another.
- What is useful & needed?

# *Efficiency*

- % Efficiency =  $100 \times (T_H - T_L) / T_H$
- For a **Single** Process.
- Typical Efficiency Values: 5 – 45%
- Suppose Many Processes are Sequenced.

# *Second Law*

- “Lack of Quality” in Energy = Entropy
- Entropy = Useful Work / Temperature
- You want Entropy to be **Small!**
- Entropy Always Rises!
- To combat this unfortunate law of nature, sequence one process to reject its “waste” Energy and feed input side of another.

# *Availability*

- Where **Does** the Process reject Energy?
- Where **Could** the Process reject Energy?
- Thermodynamically, the Difference between the two is Lost Opportunity.

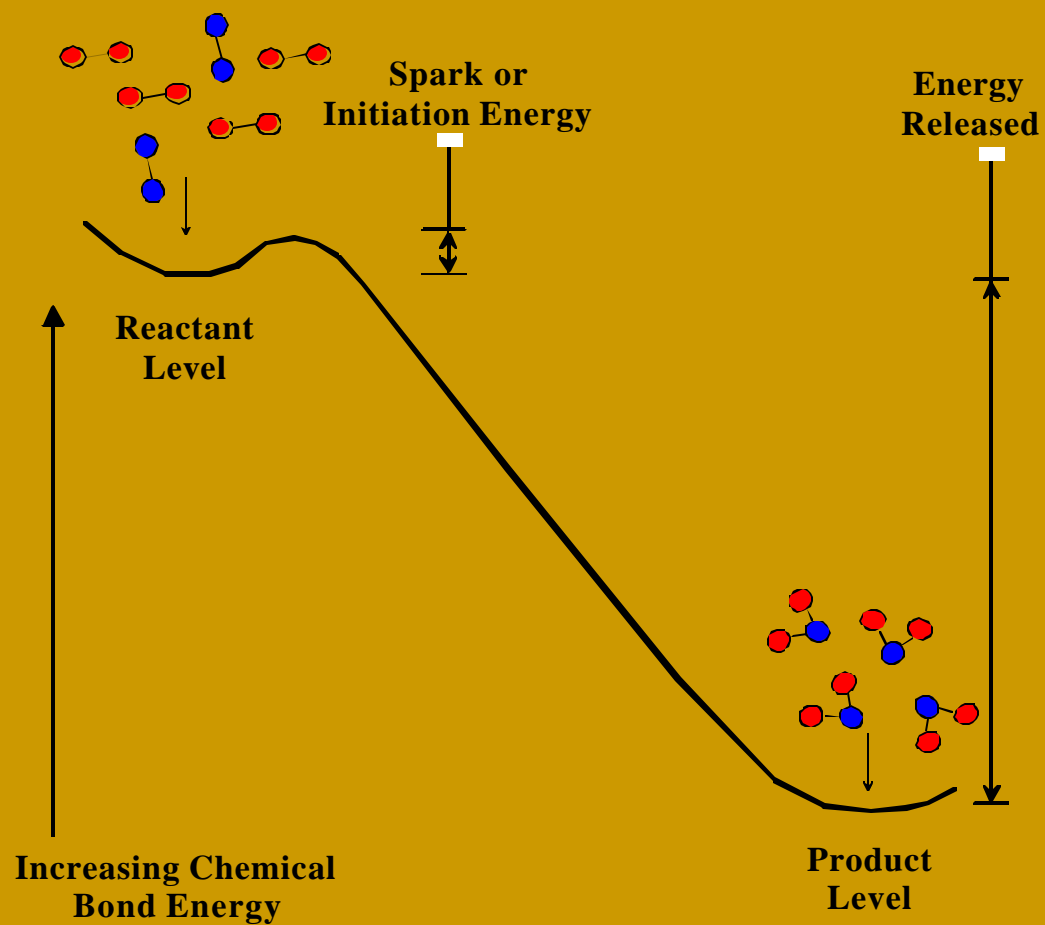
# *Combustion Fundamentals*

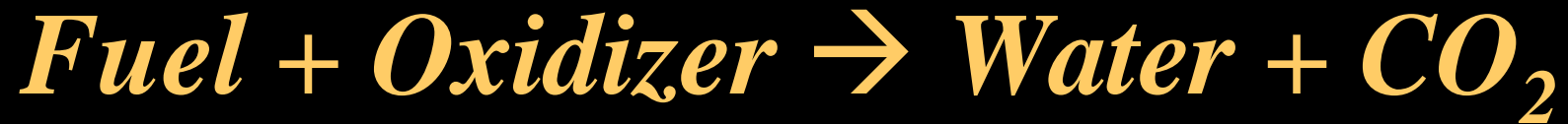
- Chemistry & Energy
- Fuel + Oxidizer  $\rightarrow$  Water + CO<sub>2</sub>
- Exact Mix vs. Lean or Rich Burn
- Impurities & Extra Materials  $\rightarrow$  Pollutants

# *Chemistry & Energy*

- Chemical Bonds hold Stored Energy
- Some Bonds hold more than others
- Hydrogen, Oxygen, Hydrocarbon Compounds hold high levels.
- Water, Carbon dioxide hold low levels.

# *The Energy 'Hill'*





- Fuel: Coal, Gasoline, Diesel, Natural Gas, Animal Waste, Plant Matter.
- Oxidizer: Oxygen, Sulfur
- Water: liquid or steam
- CO<sub>2</sub>: Not a Pollutant, Product of Reaction



## *Exact Mix vs. Lean or Rich Burn*

- Exact Mix: All Fuel & Oxidizer Used-up, **nothing** left over – gasoline engine, boiler.
- Lean: All Fuel Used-up, Oxidizer Left-over  
- diesel engine, gas turbine engine.
- Rich: All Oxidizer Used-up, Fuel Left-over  
- waste incinerators.

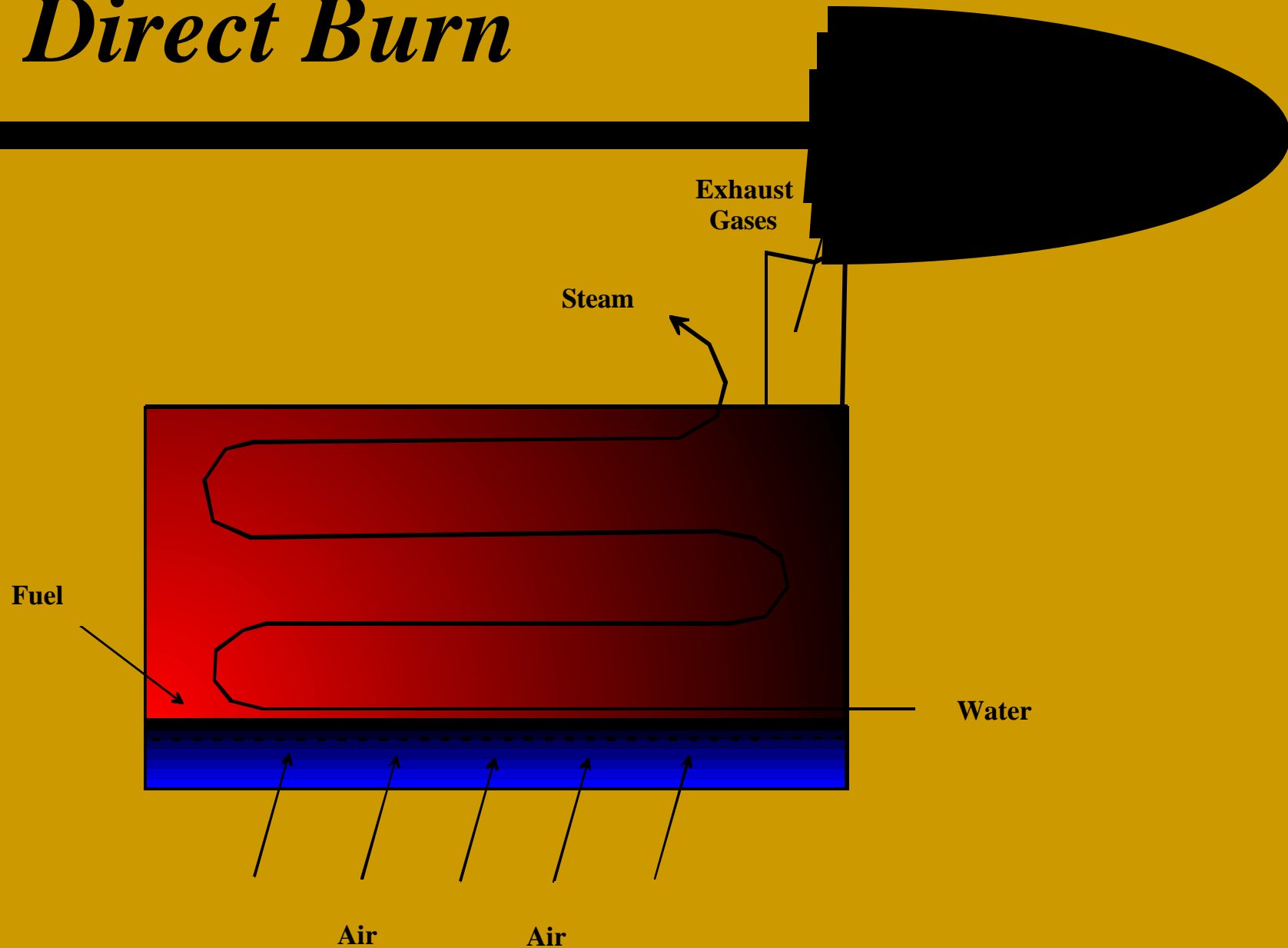
# *Impurities & Extra Materials*

- Pollutants!
- Impurities: Sulfur → Acids
- Extra Material: Nitrogen → Nitrates, Nitrites, Acids
- Left-over Fuel Reactants

# *Utilization of Combustion*

- Direct Burn
- Otto Cycle Reciprocating Engine
- Diesel Cycle Reciprocating Engine
- Brayton Cycle Turbomachinery Engine

# *Direct Burn*

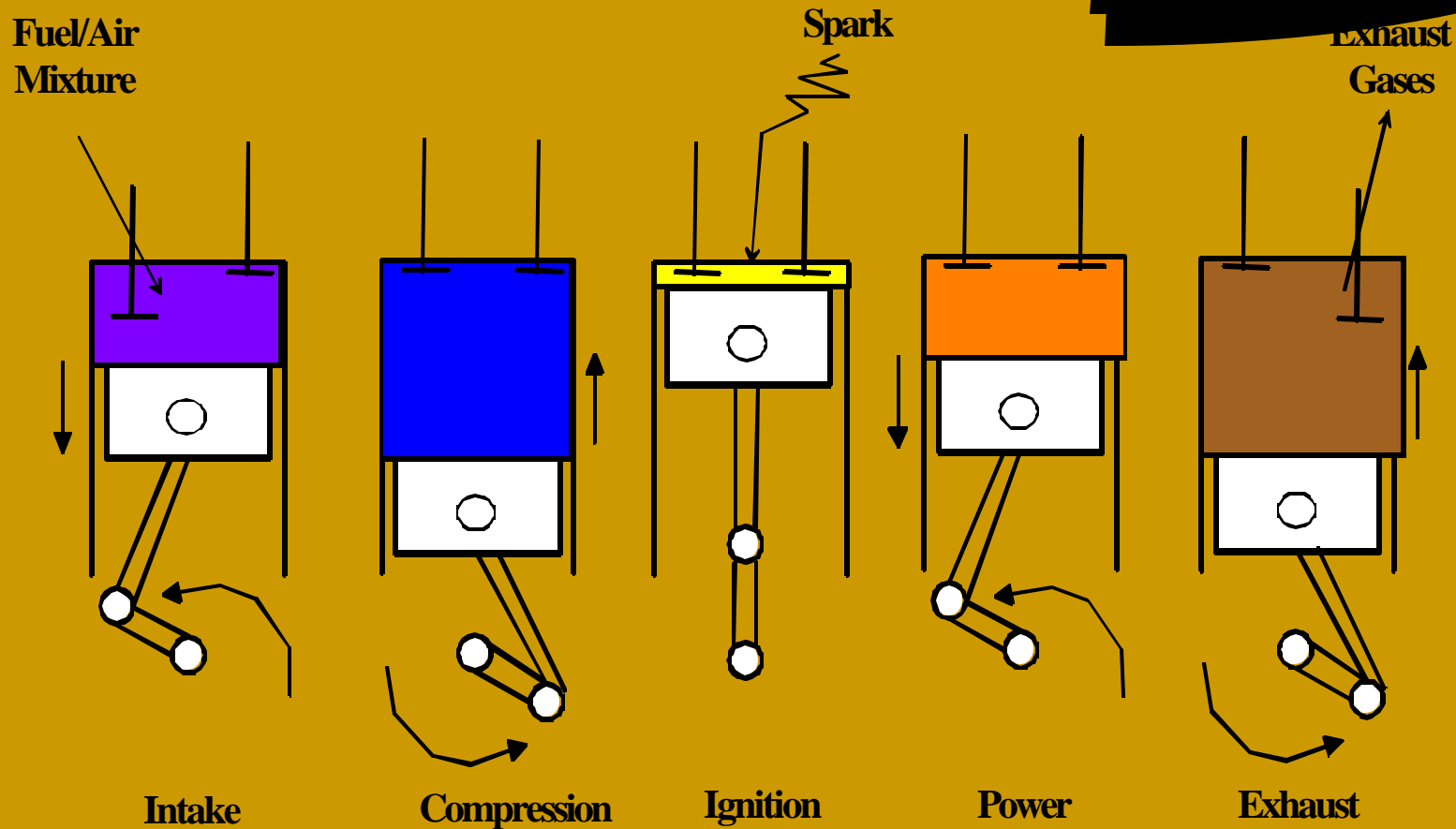


# *Direct Fire Boiler*



# *Otto Cycle*

## *Reciprocating Engine*

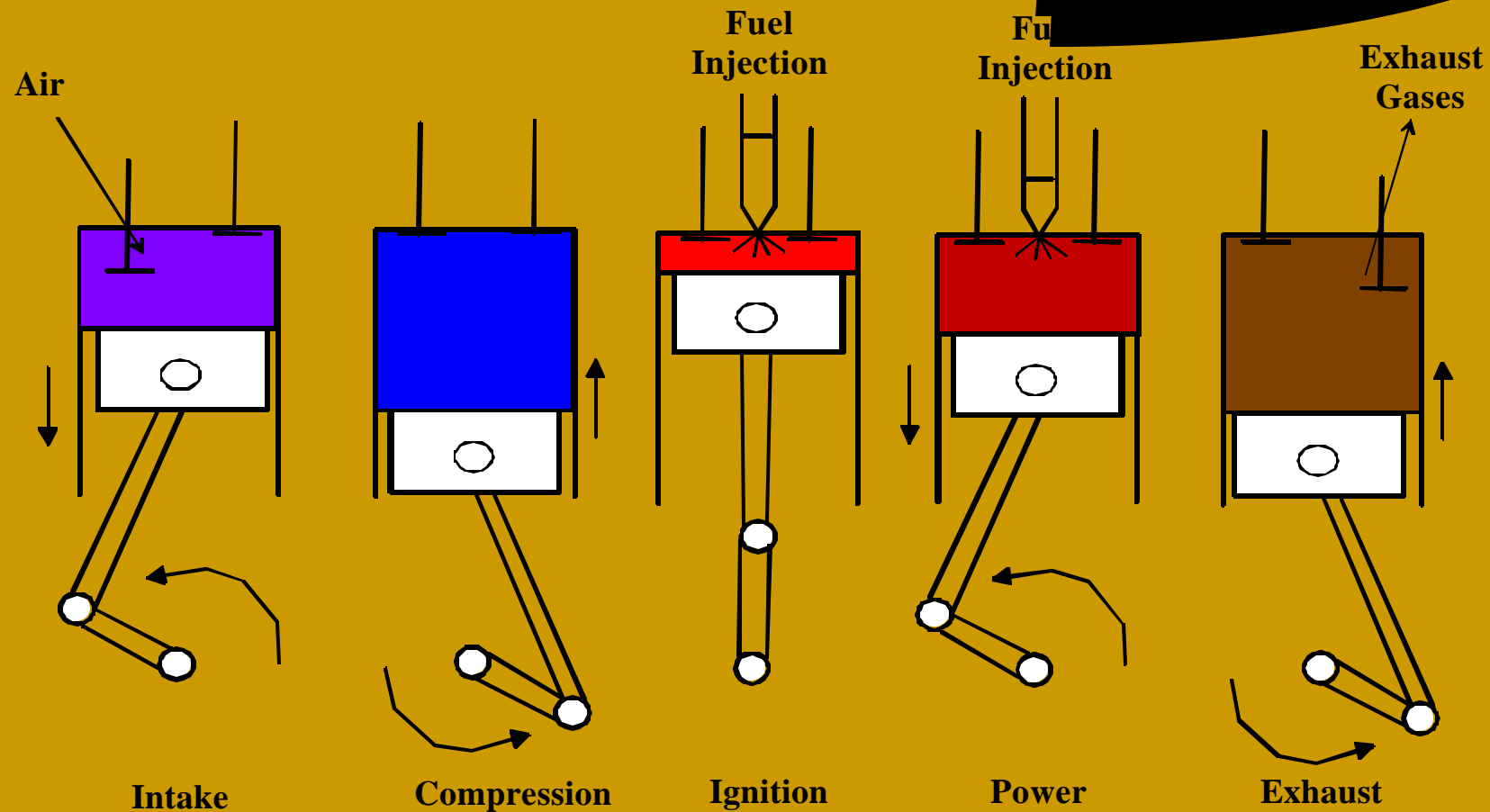


# *Gasoline Engine*



# *Diesel Cycle*

## *Reciprocating Engine*





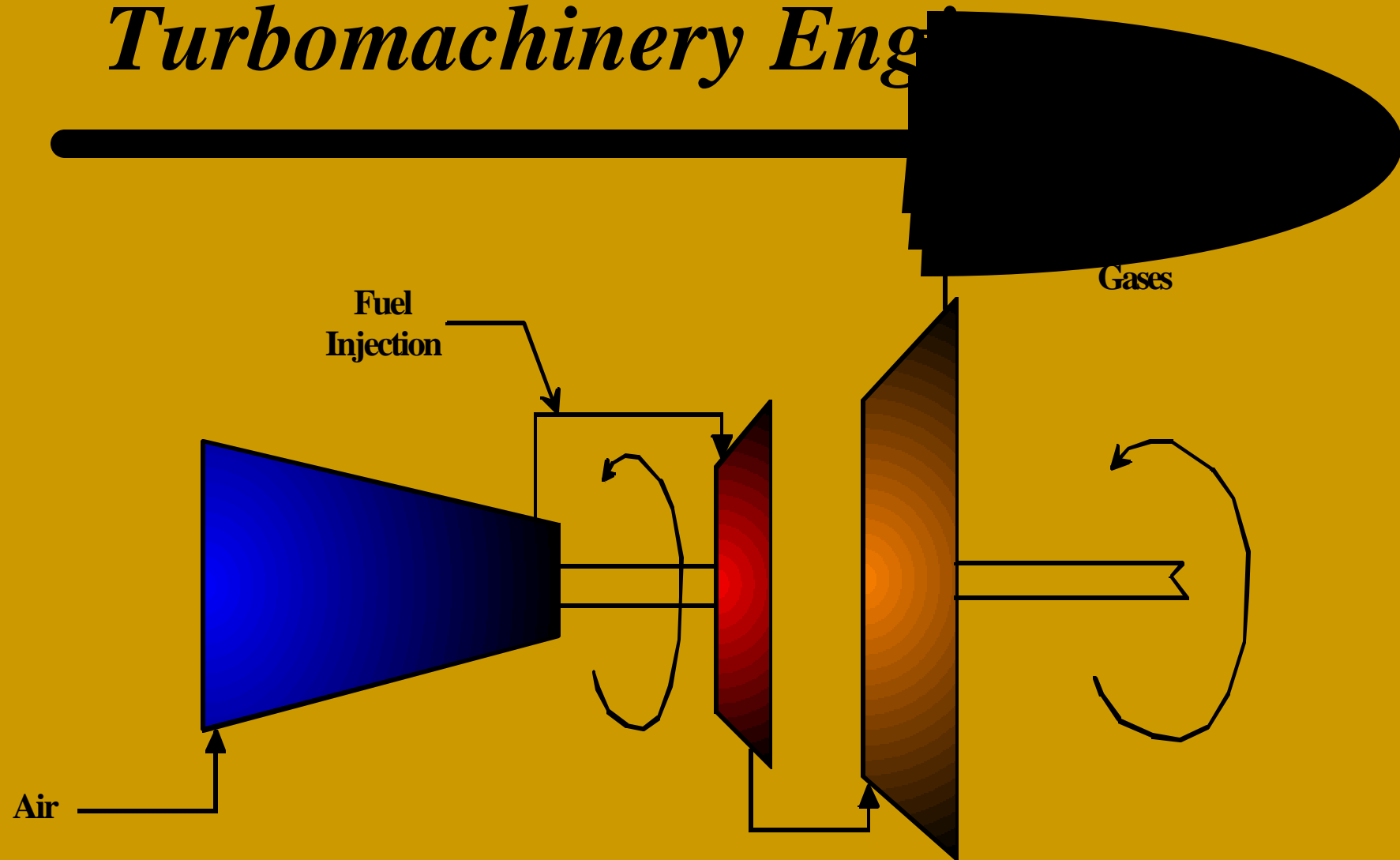
# *Diesel Engine*

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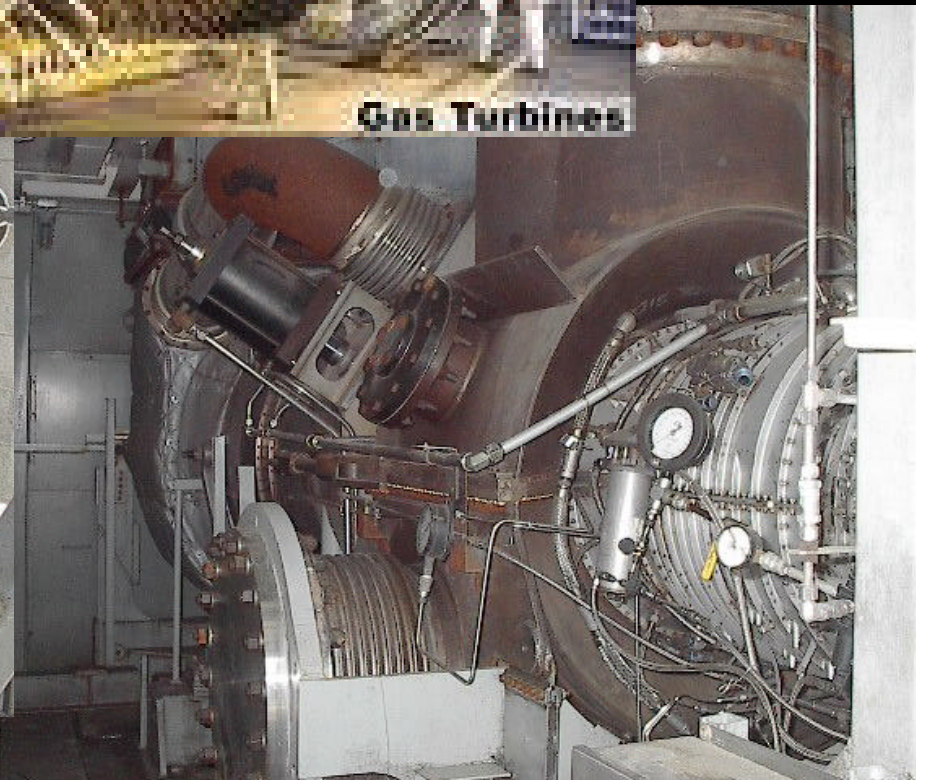
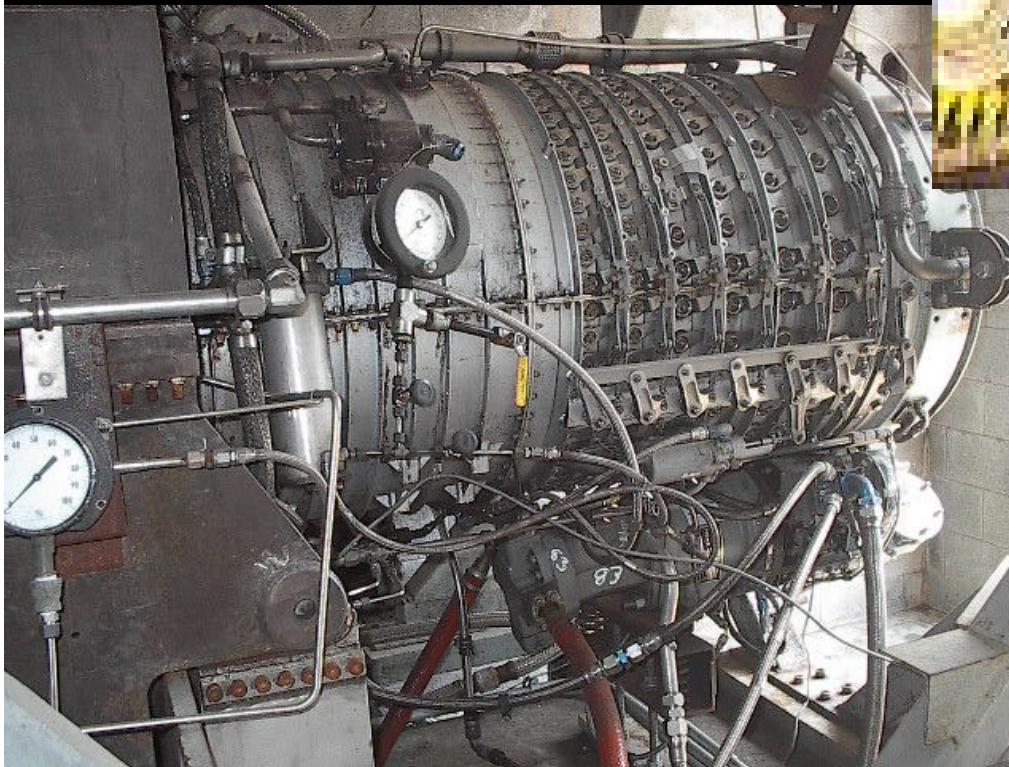


# *Brayton Cycle*

## *Turbomachinery Engine*



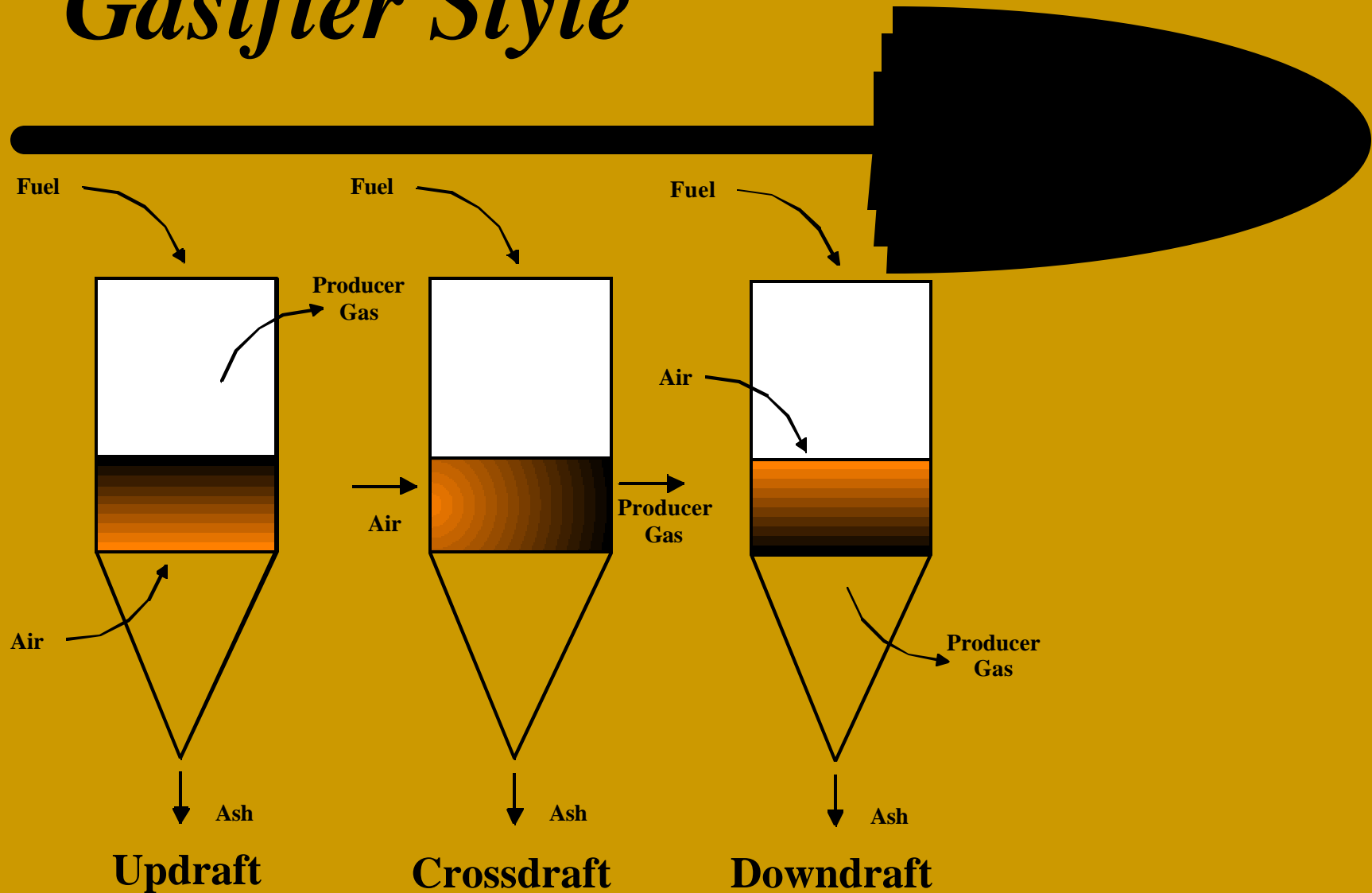
# *Gas Turbine Engine*



# *Gasification Fundamentals*

- Multi-stage Combustion
- Thermal (atmospheric)
- Steam (chemical)

# *Gasifier Style*





# *Gasifier Assembly*

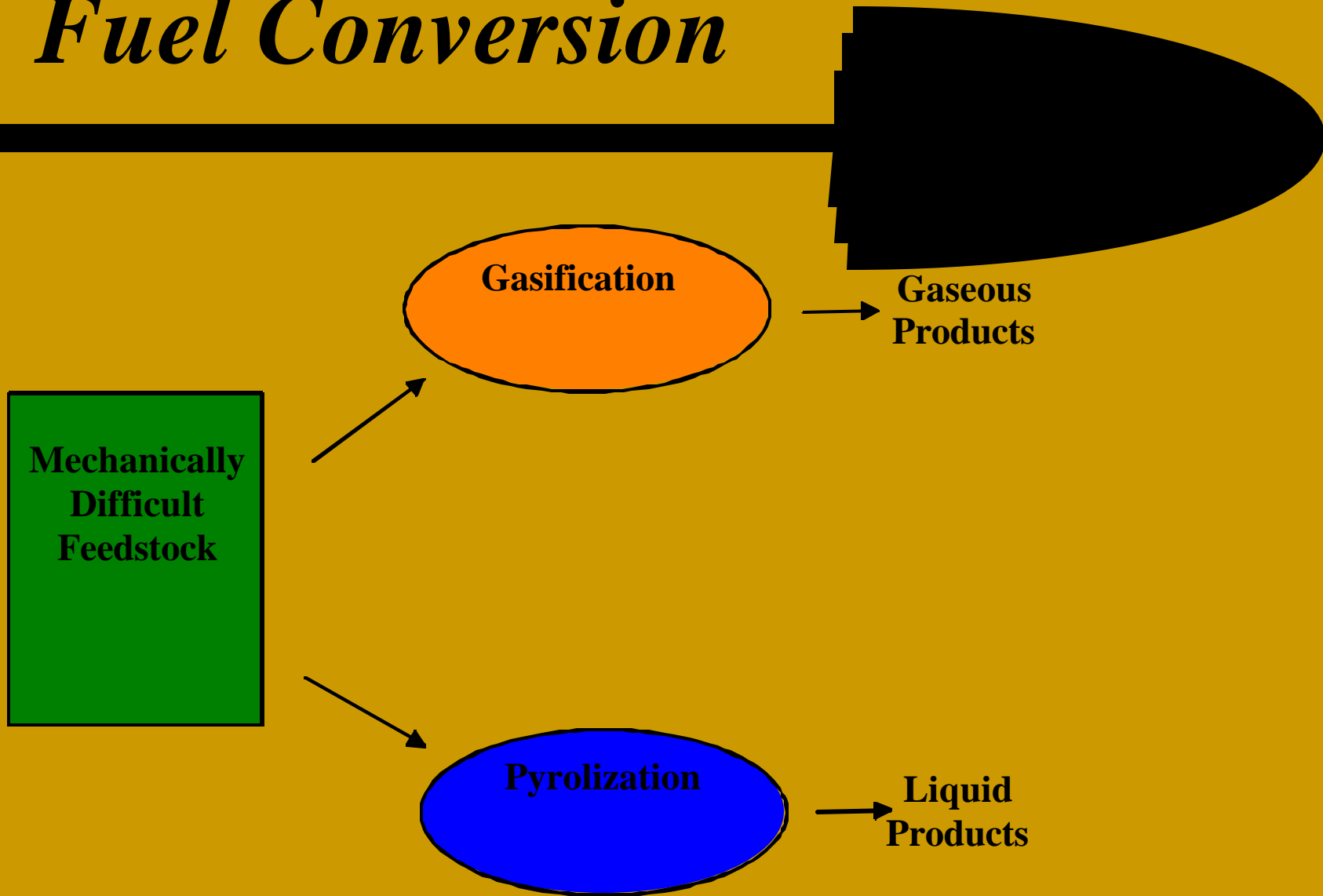


# *Utilization of Gasification*

- Fuel Conversion
- Waste Incineration
- Direct Heat
- Secondary Combustion Processes

# ***Fuel Conversion***

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# *Waste Incineration*



# *Direct Heat*

# *Secondary Combustion Process*



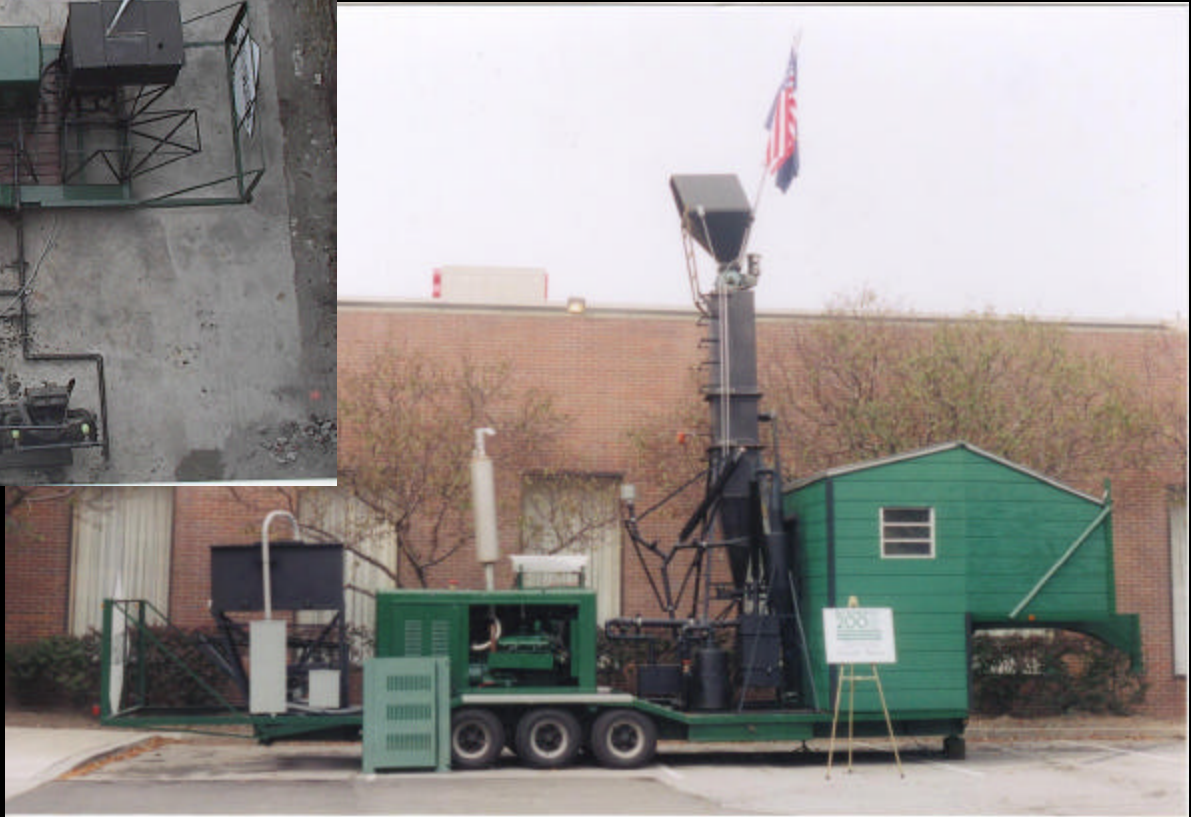
# *Energy Processes Within Our Lives and Enterprises*

- Where do we use energy?
- Where do we need energy?
- What are the possibilities?
- Is it practical to utilize?

# *Services Available*

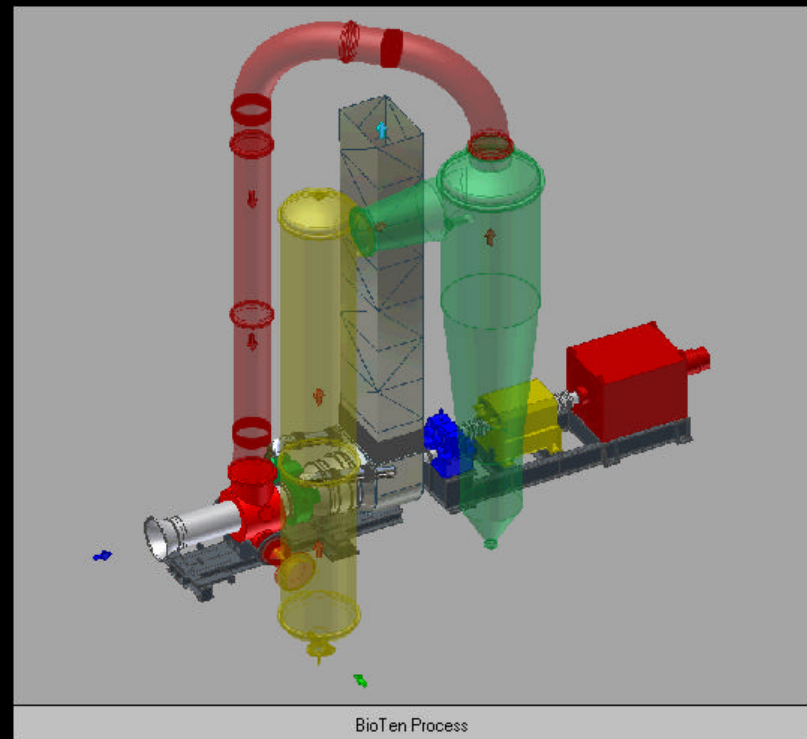
- Gasifiers
- Direct-burn Gas Turbine
- Consulting

# *Commercial Downdraft Gasifier*

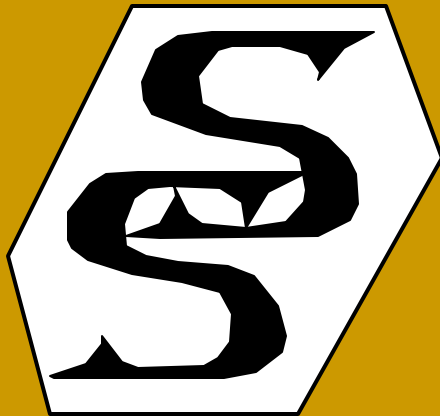
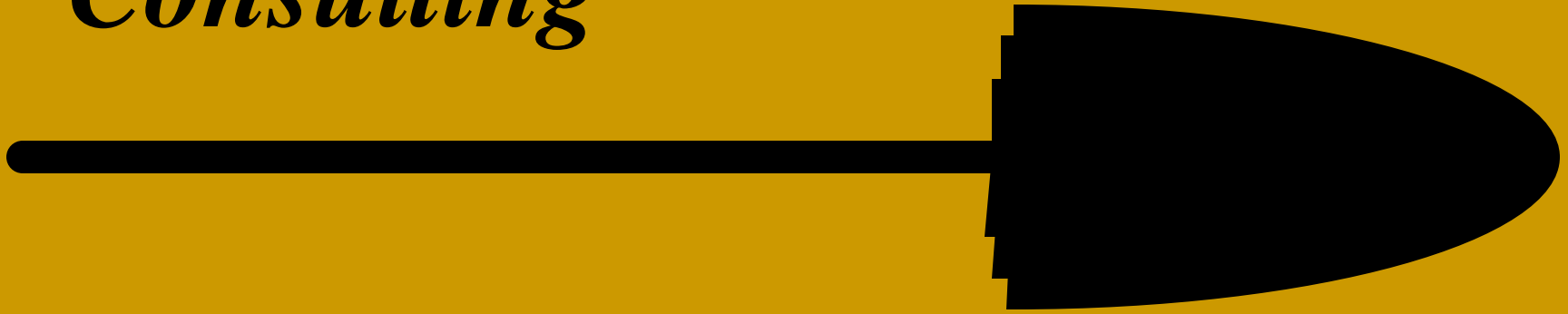


# *Solid Fuel Direct-Burn Gas Turbine*

- $5 - 10 \text{ MW}_{\text{elect}}$
- Ideal for Combined Cycle Operation
- Can be made portable



*Consulting*



**Stwalley & Stwalley  
Engineering**

[bstwalley@yahoo.com](mailto:bstwalley@yahoo.com)